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THE USE OF GABBRO FROM THE AKCHINSKII INTRUSION IN STONE CASTING AND GLASS CERAMIC PRODUCTION

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The study of rocks which differed in their chemical and mineralogic composition, age, and genesis established that gabbro from the Akchinskii intrusion can be recommended as raw materials for small heat- and acid-resistant stone casting and for production of strong and wear-resistant glass ceramic articles for various purposes.

Currently great attention in a number of countries is being paid to the development of a specific field of science and production, namely, petrugy, which solves the problem of synthesis of melted oxide materials and production on their basis of various engineering products for industry and agriculture.

The expansion of the areas of application of cast articles made of melted oxide materials ensues from the fact that these articles have sufficient strength, high density, low porosity, and high resistance to corroding and abrasive effects.

A further increase in the production volume and product range of stone-cast and glass ceramic articles is impossible without research on theoretical problems, of which the main problem is the choice of raw material.

The basis for production of high-quality stone casting is its monomineral structure. Since the silicate melts used in production of cast glass ceramic articles have a complex chemical composition and, consequently, it is difficult to achieve a monomineral structure in these materials, the main material-forming mineral ought to be capable of wide isomorphic substitutions in its lattice and satisfy in its chemical and physical properties the requirements placed on stone casting.

Pyroxenes are precisely such minerals. Numerous studies dedicated to the problems of the chemical composition of pyroxenes and their crystal optical properties have established that with respect to their structure, all pyroxenes can be considered as diopside, $\text{Ca}(\text{Mg}, \text{Fe})[\text{Si}_2\text{O}_6]$, in which sili-

con is partly and calcium and magnesium either partly, or fully replaced isomorphically by other elements with corresponding ionic radii. Thus, all oxides existing in the chemical composition of the analyzed materials can enter the composition of pyroxene if special additives ensure for a subsequent melt the stoichiometric ratio of these oxides corresponding to the structural formula of diopside.

The authors of the present work studied by the same methodic procedure rocks which differed in their chemical and mineralogic composition, age, and genesis, with the aim of determining the suitability of these rocks for stone casting and glass ceramic materials. The chemical composition of the tested rocks is given in Table 1.

Practical experience showed that the application of any single method which seeks to estimate the properties of complex petrugic melts using just one-three parameters cannot give positive results. That is why, in order to elucidate the relationship between the crystallization properties of petrugic melts and glasses and the physicochemical properties of glass ceramic materials, and the chemical composition of the initial mixtures, we used two ternary diagrams, which made it possible to increase the number of accounted parameters to six.

One of the selected diagrams was the Niggli diagram [1] which is the most informative of all those previously proposed. The Niggli diagram provides data on possible anion groups in a melt and its acidity. In order to elucidate the ratio between the modifying cations (calcium, magnesium, and iron) which, converted according to the Niggli method, mainly form a part of the M group [2], a cation diagram $\text{Ca}^{2+} - \text{Mg}^{2+} - (\text{Fe}^{2+} + \text{Fe}^{3+})$ is offered. A combination of bivalent and trivalent iron in one group is possible on compara-

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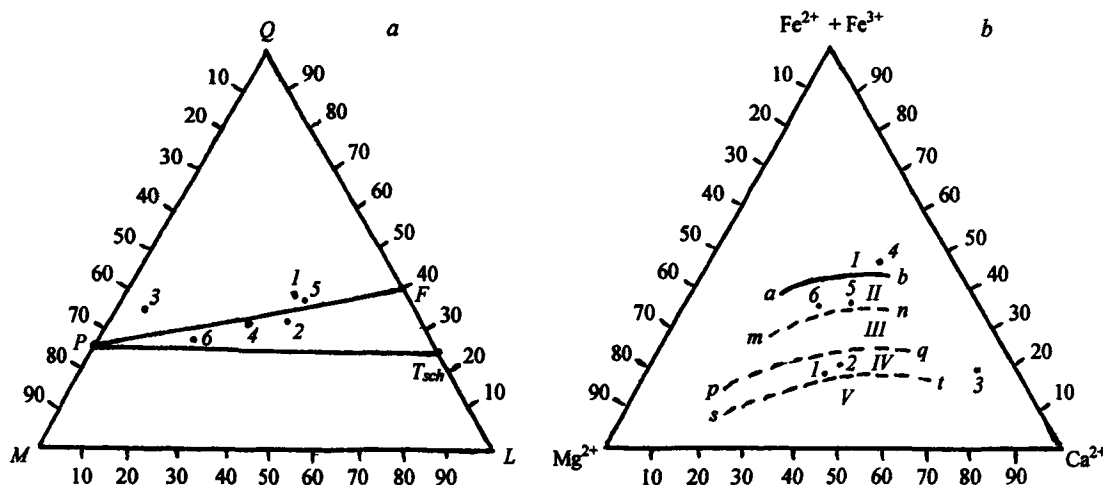


Fig. 1. Position of the compositions of investigated rocks in the Niggli diagram (a) and the cation diagram (b). L) $(\text{Na}, \text{K})\text{AlSiO}_4 + \text{CaAl}_2\text{O}_4 = 249$ (20.5%); M) $(\text{Ca}, \text{Mg})_2\text{SiO}_4 + \text{CaTiAlO}_4 + \text{Fe}_2\text{O}_3 = 886$ (52.1%); Q) SiO_2 residue = 465 (27.4%); 1–6) sample numbers (Table 1); I) field of primary crystallization of magnetite; II–V) fields of primary crystallization of pyroxene; a–b, m–n, p–q, s–t) lower dividing boundaries of respective fields.

tive analysis, when melting of rocks and crystallization of glass and melts are carried out in an environment with a constant partial oxygen pressure, and an equilibrium or nearly equilibrium ratio of $\text{FeO} : \text{Fe}_2\text{O}_3$ is established in the system.

By way of example, the chemical composition of gabbro from the Achinskii intrusion is converted using the Niggli molecular normative method (Table 2) and using the cation method (Table 3). The composition is converted into groups which include several oxides each. The groups are the basis for the stoichiometry of pyroxenes, olivines, and plagioclases. The possibility is taken into account that CaO , Na_2O , K_2O , Al_2O_3 , and SiO_2 can enter plagioclases, part of which in crystallization of the melt remains in the vitreous state. SiO_2 , CaO , MgO , and Fe_2O_3 (group M) form olivines and pyroxenes; the excessive quantity of SiO_2 with respect to these minerals is reflected in coefficient F. From the position of a point in the Niggli diagram one can estimate the viscosity and casting properties of melts and the ratio between crystalline and vitreous phases in stone casting.

The analysis of the obtained data, the Niggli diagram, and the cation diagram (Fig. 2) allow the following conclusions.

The investigated compositions belong to two series in the Niggli diagram. The compositions of the first series are located above the PF line (point P corresponds to the composition of pyroxene of the $(\text{Ca}, \text{Mg}, \text{Fe})\text{SiO}_2$ type and F corresponds to the plagioclase composition of $\text{CaAl}_2\text{Si}_2\text{O}_8 \cdot (\text{Na}, \text{K}) \cdot \text{Al}_2\text{SiO}_3$ and are characterized by an excessive content of SiO_2 with respect to the plagioclase-pyroxene composition.

The compositions of the second series are located in the pyroxene-plagioclase field inside the $P-F-T_{sch}$ triangle (point T_{sch} is the Chermak silicate $\text{CaAl}_2\text{SiO}_6$ that forms part of pyroxene) and do not contain an excess of SiO_2 . The $P-T_{sch}$ line corresponds to the monomineral composition of pyroxene.

Five fields (I–V) of compositions with a different sequence of mineral formation [2] depending on the nature of the crystallization of melts and glasses have been identified in the cation diagram.

TABLE 1

Sample number	Rock, deposit	Weight content, %								
		SiO_2	TiO_2	Al_2O_3	FeO	Fe_2O_3	MgO	CaO	Na_2O	K_2O
1	Hornblende gabbro, Shaidarkii intrusion	50.91	0.50	18.48	4.90	1.01	8.02	9.24	2.18	0.61
2	Titanium-augite gabbro, Beltau intrusion	46.80	0.86	16.63	5.88	0.67	6.93	9.45	2.63	11.60
3	Depleted skarns, Ingichka deposit	45.93	0.08	3.78	3.30	11.29	2.17	21.21	1.52	0.74
4	Gabbro-diabases, Malguzar Mountains	46.38	3.55	13.05	11.01	4.46	4.41	7.30	2.81	1.35
5	Basalts, village of Nevich	46.82	0.89	16.93	7.51	2.51	4.99	7.80	2.09	1.94
6	Gabbro, Akchinskii intrusion	43.72	0.99	9.41	–	19.32	10.84	11.46	1.33	0.91

Thus, the hornblende gabbro from the Shaidaraz intrusion and the titanium-augite gabbro from the Beltau intrusion in Kulkujau Mountains (Bukhara region), as well as the basalts from Nevich (Tashkent Region) without supplementary addition to the batch are not suitable for stone casting, since they belong to the region with primary crystallization of plagioclase ($L:M > 1$). The melts based on these materials have high viscosity and a high melting point.

The depleted pyroxene skarns from the Ingichka deposit (Samarkand region) are characterized by an increased calcium content and can be used to obtain acid-resistant articles containing wollastonite and okkermanite.

The gabbro diabase from the Malguzar Mountains dike (Dzhizak region) can be used to obtain products with low heat resistance, since its composition in the cation diagram related to the field of the primary crystallization of magnetite. This results in spontaneous crystallization of melts due to crystallization centers caused by primary release of magnetite.

The composition of gabbro from the Akchinskii intrusion (Tashkent region) belongs to the second series of the Niggli diagram. Such compositions with $L:M < 1$ in most cases belong to the field of primary crystallization of pyroxene. The typical features of the compositions related to this field consist in the absence of magnetite as the primary equilibrium phase and release of magnetite only at the moment of crystallization of pyroxene.

Taking into account the above, the specific features of gabbro from the Akchinskii intrusion were investigated in more detail in order to finally establish the expediency of using this raw material in development of stone-cast and glass ceramic materials.

The mineral composition of the tested rocks is as follows (%): 40–60 plagioclase, 10–20 augite, 14–20 hornblende, 5–7 biotite, 5–10 sericite, 3–5 chlorite, 5–10 calcite, up to 3 leucoxene, 1–3 epidote, 3–5 magnetite.

It was found that the main rocks of the Achinskii intrusion vary significantly in their mineral and chemical compo-

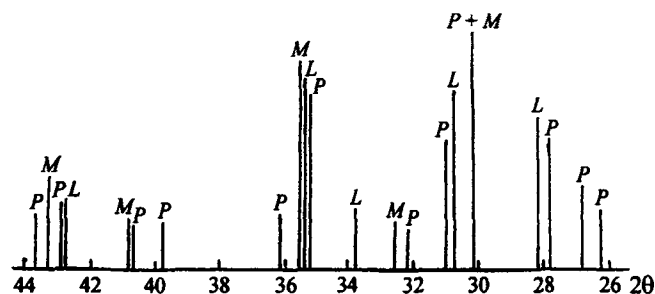


Fig. 2. X-ray diffraction pattern of crystallized glass. P) Pyroxene, L) plagioclase – labrador; M) magnetite.

sition, which is manifested by the existence of different types of rocks: from ultrabasic types (wehrlites, troctolites, and anorthosites) to basic types (pyroxene-hornblende, hornblende, biotite-hornblende gabbro) which constitute nearly 90% of the total rocks of the Akchinskii intrusion.

The virtually unlimited amount of gabbroids suitable for petrugical purposes, their location near an energy source (the Novoangrenskaya power plant) and main transport routes, the available roads, and geological conditions that allow open-cast mining make gabbro from the Akchinskii deposit a highly promising and economically efficient petrugic material.

Melts and glasses produced in melting of gabbro rocks in the focal zone of a big solar furnace (1000 kW/sec) and in laboratory resistor furnaces were investigated.

As was already noted, the tested rocks relate to the second series of the Niggli diagram, i.e., primary crystallization of pyroxene (field II in Fig. 1).

In melts resulting from oxidizing melting, iron cations are fully assimilated by proembryonic pyroxene groups. Therefore, the absence of magnetite determines the propensity of the melt toward supercooling.

The separation of crystal phases from a gabbro melt (crystallization "from above") starts at the temperature of

TABLE 2

Oxide	Weight content, %	Atomic quantities × 1000*	Initial standard groups					
			(Na, K)AlSiO ₄	CaAl ₂ O ₄	CaTiAlO ₄	(Ca, Mg) ₂ SiO ₄	Fe ₂ O ₃	SiO ₂
Na ₂ O	1.33	42	42	—	—	—	—	—
MgO	10.84	269	—	—	—	269	—	—
Al ₂ O ₃	9.41	185	42 + 18	113	12	—	—	—
SiO ₂	43.72	728	42 + 18	—	—	68 + 135	—	465
K ₂ O	0.91	18	18	—	—	—	—	—
CaO	11.46	204	—	56	12	136	—	—
TiO ₂	0.99	12	—	—	12	—	—	—
Fe ₂ O ₃	19.32	242	—	—	—	—	242	—

* The atomic quantities are determined by division of the mass content by the molecular mass and multiplication by the number of atoms in the molecule.

TABLE 3

Oxide	Weight content, %	Atomic quantities	
		× 1000	%
CaO	11.46	204	28.5
MgO	10.84	269	37.6
Fe ₂ O ₃	19.32	242	33.8

1100°C from the melt surface, and the amount of these phases does not exceed 20% of the volume. On abruptly cooling a melt to 900°C and holding it at this temperature for 1 h, a finely crystalline glass ceramic material consisting of magnetite and pyroxene is formed. The propensity of gabbro melt to supercooling prevents obtaining crystal materials without introduction of nucleators. Chromite (1–2 wt.%) introduced in the tested rock before melting can be a nucleator. Glass tempered from the melting point is not acid-resistant (< 50%), however, on holding the melt in the liquidus – vitrification interval (1100–650°C), the acid resistance increases to 94–98%.

In the case of heat treatment of glass “from below” at a temperature up to 800°C, an increase in magnetic sensitivity is observed, which is indicative of separation of magnetite. However, crystalline phases are absent in the x-ray patterns, which can be attributed to an insignificant amount of magnetite formations. Heating at the temperature of 850°C results in the appearance of pyroxene reflections in the x-ray diffraction pattern. On further heat treatment of the glass, a fine crystalline glass ceramic material consisting of magnetite, pyroxene, and plagioclase is formed, whose grain size is below 1 μm (Fig. 2)

Thus, initial nonequilibrium release of magnetite acting as crystallization centers in glass determines the fine volumetric crystallization of glass.

The x-ray diffraction patterns of the crystallized glass exhibit a doublet in the region of angles $2\theta = 30 - 32^\circ$ (Fig. 2), regardless of the heat treatment temperature. As shown in [2], a doublet in the x-ray diffraction patterns in the region of the specified angles is a diagnostic indicator of subcalcium augites and pyroxenes of the pigeonite group. Therefore, gabbro glass in heat treatment releases pyroxenes of the pigeonite type.

We investigated the specific features of the crystallization of melted gabbro in the conditions of powder technology.

The study of the effect of the coarseness of the initial powder revealed that an increase in the dispersion from 3000 to 8000 cm²/g produces a decrease in the final temperature of firing by 30–50°C. At the same time, DTA revealed a decrease in the temperature boundaries of the phase transitions.

As a consequence of the experiments, a glass ceramic material with a microcrystal structure was obtained, which had the following parameters: firing temperature of the product: 1210°C, bending strength: 146 MPa, water absorption — 0.04%, open porosity — 0.14%, apparent density — 2.87 g/cm³, abrasion resistance — 0.041 cm³/cm², acid resistance (according to GOST 473–64) — 99.1%.

Technology for thermoplastic molding of articles based on melted gabbro has been developed, and a prototype lot of thread guides for the textile industry has been manufactured.

Thus, gabbro from the Akchinskii intrusion can be recommended as raw material for small-sized heat- and acid-resistant stone casts and for production of strong and wear-resistant glass ceramic articles for wide application.

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